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New records of agaricoid macrofungi (Agaricales, Basidiomycota) in an urban fragment of tropical dry forest from Colombian Caribbean Region

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Abstract. Three new records of Agaricales species from the Colombian Caribbean region are presented: *Agrocybe pediades* (Fr.) Fayod, *Macrocybe titans* (H.E. Bigelow & Kimbr.) Pegler, Lodge & Nakasone, and *Podaxis pistillaris* (L.) Fr. Descriptions, photographs, and illustrations of the macroscopic and microscopic features of each species are presented, as well as a brief discussion of their distribution.

Keywords. Biodiversity, fungi, macrofungi, tropical dry forest, urban reserve

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Introduction

Agaricales (Agaricomycetes, Basidiomycota) comprise the largest order in the kingdom Fungi with about 25,000 described species according to the Catalogue of Life database. This richness is spread among 38 families and 642 genera (Bánki et al. 2022). In this diverse group, the taxonomy is determined by the morphology of the hymenophores arranged in sheets that include differential macroscopic characteristics such as the pileus (size, shape, and texture); stipe (thickness, edge, color, arrangement, and insertion of the sheets); morphology, color, appearance, and consistency of the stipe; presence or absence of ring, volvas or curtain; and spore print, in addition to organoleptic qualities (Largent 1986; Singer 1986). Additionally, microscopic characteristics include the number, morphology, ornamentation, and coloration of the basidiospores, shape and location of cystidia, and arrangement of the hyphae of pileipellis, in addition to the reactions against Melzer's iodine reagent, KOH and ammonia Congo red (Pegler 1983). Including molecular techniques in basic fungal research is of great help, especially in cases where it is not possible to know the taxonomic identity of the species from morphology alone (Raja et al. 2017), although molecular approaches to fungi inventories are still limited in Colombia (Gaya et al. 2022).

The ColFungi project (https://colfungi.org/) has recently recognized 7,241 accepted species of fungi in Colombia; these encompass a diversity of fungal life forms, such as mushrooms, lichenized fungi, pathogenic microfungi, moulds, and yeasts, along with others (Gaya et al. 2022). In the country, Agaricales is the order with the most species, totaling 833 of the 2,318 fungi species of the phylum Basidiomycota (Cossu et al. 2022; Franco-Molano et al. 2022).

However, most of studies have focused on the Andean region, especially in the departments of Antioquia, Valle del Cauca, and Cundinamarca, with the best sampled ecosystems being oak forests, mixed forests, and lowland forests (Gómez-Montoya et al. 2022; Franco-Molano et al. 2022). In the department of Magdalena, 212 species of macrofungi have been recorded, of which 45 belong to Agaricales (Gomez-Montoya et al. 2022), and additional species have been recorded recently more, increasing the fungal richness for this department (Luna-Fontalvo et al. 2021). Magdalena is characterized by tropical dry forest, one of the most threatened ecosystems in Colombia (Pizano and García 2014).

Colombian funga is one of the richest in South America due to Colombia's geological history, topography, climate, wide range of vegetation types, and high biodiversity. The importance of macrofungi is indisputable in ecosystems, and there is still basic knowledge lacking on taxonomic diversity, biology, and distribution patterns of macrofungi both worldwide and in Colombia (Gómez-Montoya et al. 2021). Here, we present new records from for Magdalena of the three species of Agaricales. Additionally, we include notes on morphology (illustrating micromorphological characters), distribution, and habitat.

Methods

The specimens were collected in the rainy season from October 2018 to October 2019 (Mueller and Bills 2004; Lodge et al. 2004). The specimens were documented and preserved according to standard methods (Lodge et al. 2004), and the type of habitat and associated substrate were recorded. Taxonomic characters in fresh specimens, such as basidiomata color and spore prints, were recorded. Each specimen was photographed with a Nikon D7000 digital camera, and a color chart was used for color names and codes (Kornerup and Wanscher 1978).

Microscopic analysis of the collected material was performed with a Nikon stereoscope and a Zeiss Primo Star microscope with attached camera. All the measurements and colors described here were obtained from material rehydrated in KOH 5%, alcohol 70%, and water, and Congo Red and Melzer Reagent were also used. The preparations were observed with an immersion objective (100×), and structures were described following standardized techniques (Largent et al. 1977; Largent 1986; Largent and Abell-Davis 2011). Measurements of microscopic structures were made using ToupView v. 3.7. Forty basidiospores were measured to determine the Q value (length/width ratio), the sample size was determinate by $n = x/y$ (where x is the total number of measured basidiospores and the number of basidiomata studied). To identify species, specialized literature was consulted (Singer 1976; Singer 1986; Pegler 1983; Kuo 2007; Petersen and Lassoe 2012). Index Fungorum (2023; https://www.indexfungorum.org/) was consulted for the names of the species, synonyms, and authors. The specimens were deposited at the Centro de Colecciones Biológicas de la Universidad del Magdalena (CBUMAG).

Data deposition. The data underpinning the analysis reported in this paper are deposited in the Global Biodiversity Information Facility (GBIF 2022) and are available at https://doi.org/10.15472/p16ua9 (Luna-Fontalvo et al. 2022).

Study Area

The study area was located on the campus of the Universidad del Magdalena, a departmental public university whose headquarters are in the city of Santa Marta, capital of Magdalena (Fig. 1). With an area of 52 ha, the main campus consists of different buildings: administrative areas, classrooms, laboratories, cafeterias, and sports venues. In addition, it has several green areas, an artificial lake, an experimental farm for crops, ponds for fish farming, and an urban fragment of secondary-regenerated tropical dry forest (Barranco-Pérez et al. 2016; Castellanos-Barliza and Barranco-Pérez 2019). All the above turns this campus into a matrix of heterogeneous environments, which can be inhabited by a variety of fungal life forms (Luna-Fontalvo et al. 2021; Atencia Meza et al. 2022).

The climate of this region of Colombia is characterized by a bimodal rain regime with two wet seasons (May to June and September to November) and two dry seasons (December to April and June to August), an annual average rain of 578 mm, and an annual average temperature of 29 °C. Also, the mean relative humidity is 74%, with a semi-arid climate with a high water deficit in the dry season (Rangel and Carvajal 2012).

Results

Three species of Agaricales are newly reported from the department of Magdalena: *Agrocybe pediades* (Fr.) Fayod (Strophariaceae), *Macrocybe titans* (H.E. Bigelow & Kimbr.) Pegler, Lodge, & Nakasone (Callistosporiaceae), and *Podaxis pistillaris* (L.) Fr. (Agaricaceae). Two of these species are reported from the Caribbean region of Columbia for the first time.

Strophariaceae

***Agrocybe pediades* (Fr.) Fayod**

Figure 2

New records. COLOMBIA – **Magdalena** • Santa Marta, Universidad del Magdalena; 11°13′18″N, 074°11′08″W; 24.IX.2019; J.Luna-Fontalvo et al. leg.; JLF | CAS | ABY 039; UMAG:CBUMAG:FUN:13.

Identification. Pileus applanate to slightly convex, 18–30 mm in diameter, Persian orange (6A7), and darker towards the center, with a dry and smooth surface; entire border with whitish partial veil traces and straight margin (Fig. 2A). Lamellae brownish yellow

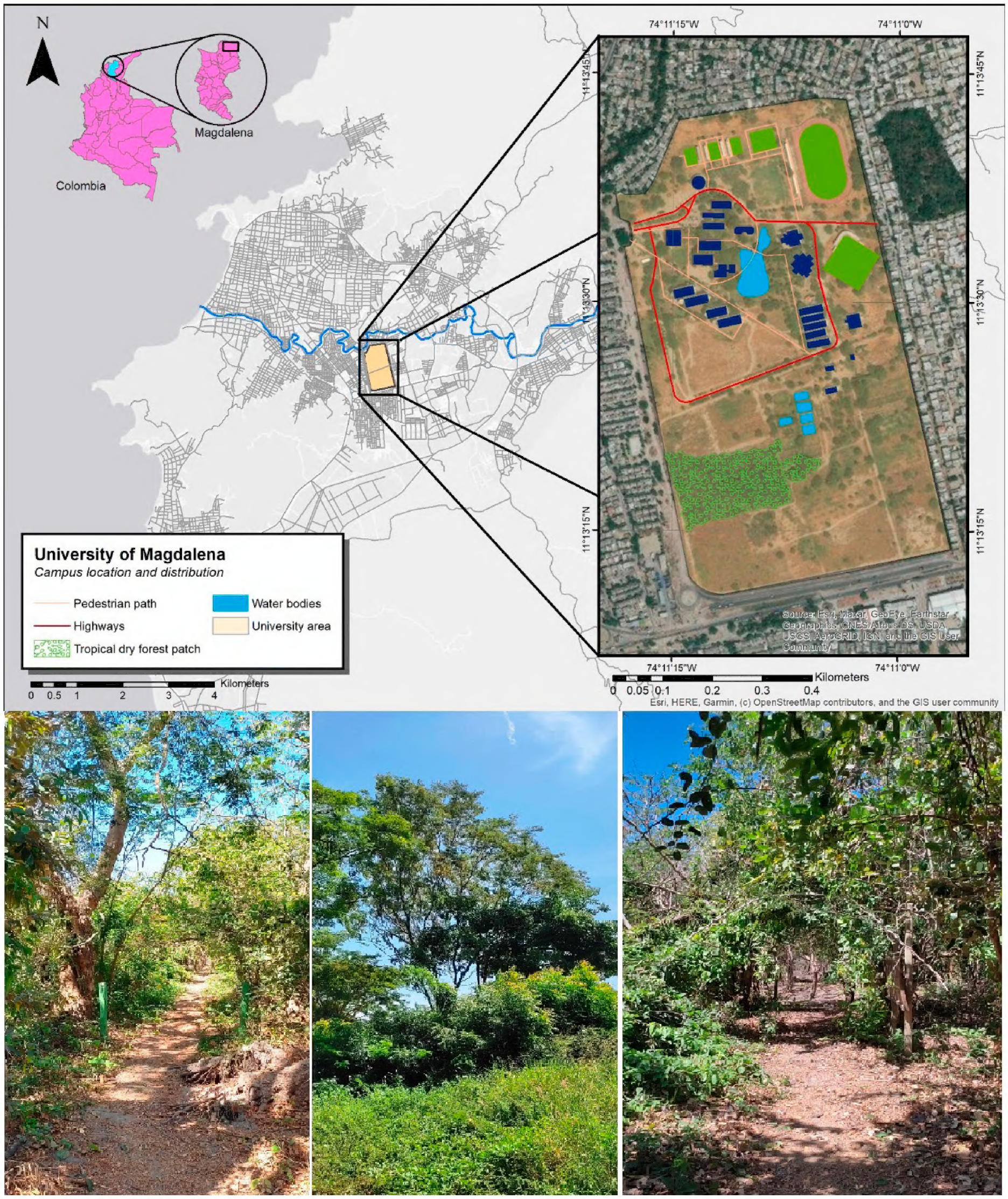

Figure 1. Universidad del Magdalena main campus in Santa Marta, Magdalena, Colombia, and the urban fragment of tropical dry forest.

(5C4), adhered to the stipe, acute, distant, with a wavy edge and lamellulae. Stipe concolorous with hymenium and trama, 75–80 × 3–5 mm, central, cylindrical, flexuous, fibrous, and scaly; base with mycelial cords. Trama sparse, thin, and consistent (Fig. 2B, C).

Basidiospores yellowish-brown (5E8), 8.24–13.16 × 5.33–8.69 µm (X = 11.22 ± 1.028 × 7.21 ± 0.7141; Q = 1.56 0.1213; *n* = 40/3), ellipsoid, truncated, thick-walled, with granular content and germ pore (Fig. 2D). Basidia 25.29–31.10 × 6.97–8.59 µm, hyaline, claviform, tetrasporic, with thin wall, some present granular contents (Fig. 2E). Cheilocystidia 15.90–31.78 × 5.20–10.49 µm, hyaline, fusiform, subcapitate to capitate (Fig. 2F). Pleurocystidia 16.81–26.40 × 7.25–10.33 µm, hyaline, lageniform to utriform (Fig. 2G).

The description of our collection of *A. pediades* in the present study are similar to specimens from Brazil (Calaça et al. 2020) but with the size of the spores smaller in the Colombian material. Morphological similarities of *A. pediades* with other species of the

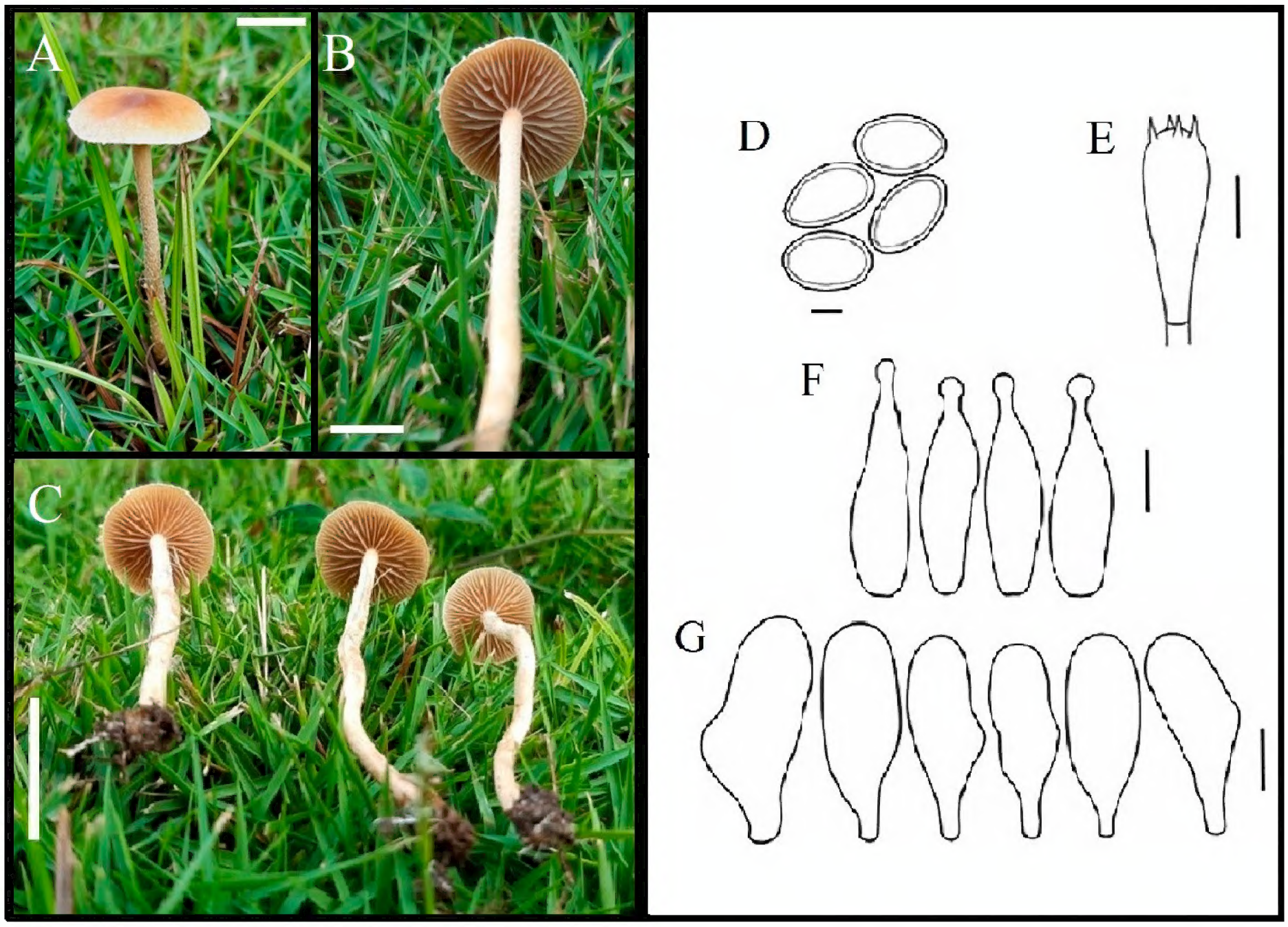

Figure 2. Basidiomata and microscopic structures of *Agrocybe pediades*. **A.** Lateral view of the pileus. **B.** Details of the hymenium and stipe. **C.** Basidiomata. **D.** Spores. **E.** Basidia. **F.** Cheilocystidia. **G.** Pleurocystidia. Scale bars: A, B = 1 cm; C = 2 cm; D = 10 µm, E–G = 20 µm.

genus have led to consideration that *A. pediades* is a complex of highly morphologically variable species (Nauta 2004). Among the species most closely related to *A. pediades* are *A. cubensis* (Murrill) Singer, *A. fimicola* (Speg.) Singer, and *A. semiobircularis* (Bull) Fayod, which are distinguished by macroscopic, microscopic, and ecological characteristics, such as substrate preference. *Agrocybe cubensis* grows on dead plant material, while also presenting an appendiculated veil and tetrasporic basidia (Calaça et al. 2020). Nauta (2004) proposed *Agrocybe fimicola* as a variety of *A. pediades* and considered it to belong to a complex of three varieties (*A. pediades* var. *fimicola*, *A pediades* var. *cinctula*, and *A. pediades* var. *pediades*). *Agrocybe semiobircularis* is extremely similar and is considered by some authors a synonym; however, it has bisporic basidia, larger spores, and more yellowish tones in the pileus (Thomas and Manimohan 2003).

Habitat and distribution. Terrestrial species, on grass, with a scattered growth habit, collected in the rainy season; it also presents a coprophilic habit and has been recorded growing on dung (Calaça et al. 2020). This species is cosmopolitan and has been recorded on all continents except Antarctica (GBIF Secretariat 2022). In the Neotropical region it is present in Mexico (Guzmán 1972; Herrera et al. 2006), Argentina (Coimbra 2015; Niveiro et al. 2020) and Brazil (Calaça et al. 2020). This is the first record for Magdalena and the Colombian Caribbean region; in Colombia, it was previously recorded in Cundinamarca (Gómez-Montoya et al. 2022).

Callistosporiaceae

***Macrocybe titans* (H.E. Bigelow & Kimbr.) Pegler, Lodge & Nakasone**

Figure 3

Material examined. COLOMBIA – **Magdalena** • Santa Marta, Universidad del Magdalena; 11°13′18″N, 074°11′08″W; 01.X.2019; J.Luna-Fontalvo et al. leg.; JLF | CAS | ABY 052; UMAG:CBUMAG:FUN:15.

Identification. Pileus convex when immature, 80–100 mm in diameter, yellowish-gray (4B2), with a yellowish-brown central spot (5E4); dry, smooth, and opaque surface; rolled margin and entire edge (Fig. 3A). Lamellae gray-white (5B1), sinuous, tight, and with lamellulae. Stipe concolorous with pileus, 70–110 × 20–38 mm, central to eccentric, spongy, and cylindrical to clavate, with squamulous surface. Trama thick white (Fig. 3B).

Basidiospores hyaline, 5.9–6.65 × 3.85–5.69 µm (X = 6.27 ± 0.23 × 4.53 ± 0.51; Q = 1.39 ± 0.14; *n* = 12/3), subglobose to broadly ellipsoidal, with smooth and thin wall, no germinative pore distinguishable (Fig. 3C). Basidia 26.04–37.19 × 6.21–8.57 µm, hyaline,

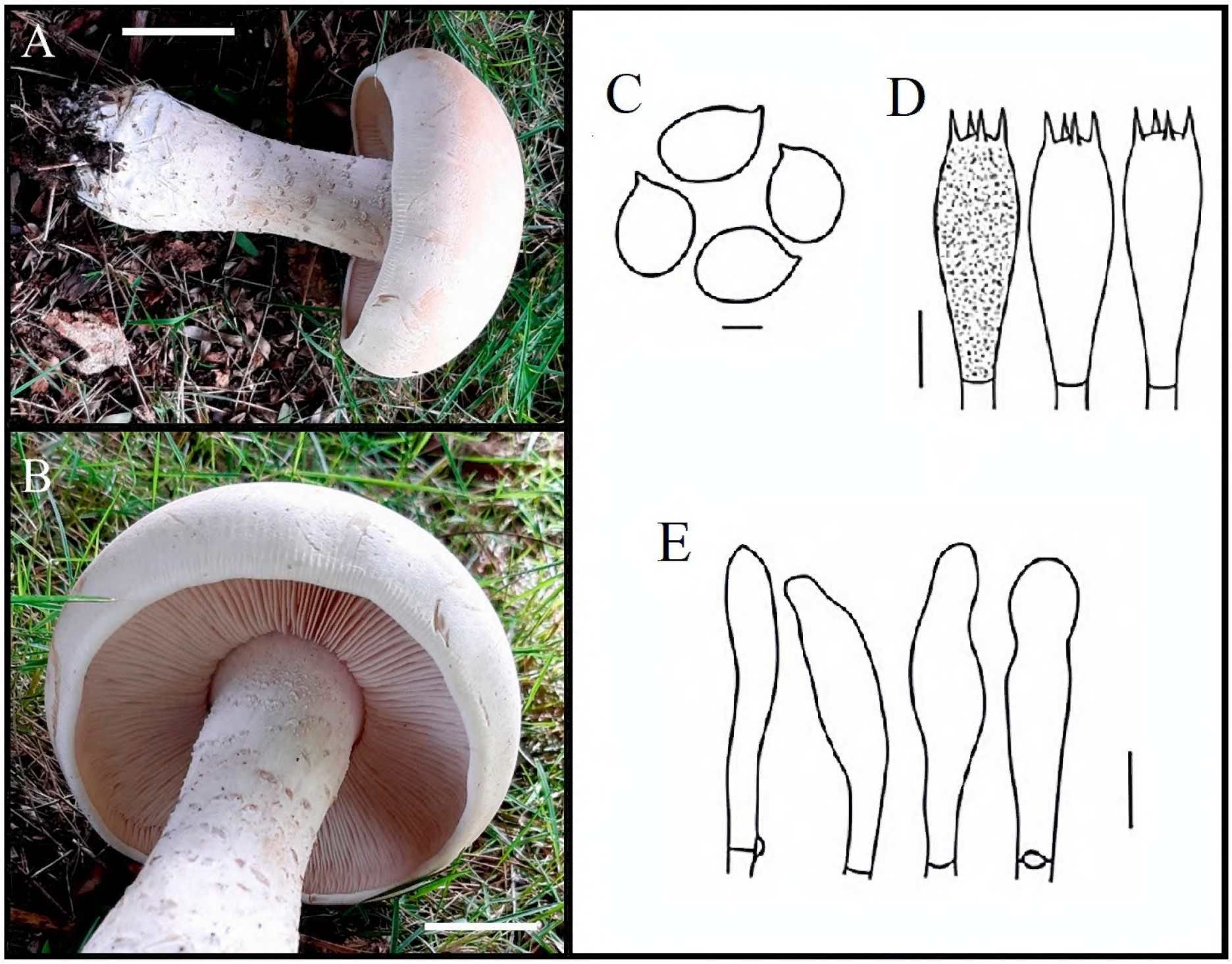

Figure 3. Basidiomata and microscopic structures of *Macrocybe titans*. **A.** Lateral view of the basidiocarp. **B.** Details of the hymenium and stipe. **C.** Spores. **D.** Basidia. **E.** Pseudocystides. Scale bars: A, B = 3 cm; C = 10 µm; D, E = 20 µm.

tetrasporic, claviform to cylindrical (Fig. 3D). Pseudocystidia 24.94–35.45 × 4.17–7.09 µm, fusiform to filiform, with thin apices (Fig. 3E).

Macrocybe titans can be macroscopically characterized by the squamulose stipe, and microscopically by the numerous pseudocystidia. The pileus can vary from 8–100 cm in diameter (Pegler et al. 1998); however, Corrales and López (2005), Piepenbring (2008), and Ramírez et al. (2017) have reported smaller pilei. *Macrocybe titans* has spores of 5.5–7.0 × 4.0–5.0 (6.12 ± 0.90 × 4.32 ± 0.29) µm and Q = 1.42 (Pegler et al. 1998). *Macrocybe pachymeres* is similar to *M. titans* in coloration of the basidiomata, in the squamulous surface of the stipe, and in the size of the spores; however, it presumably does not have pseudocystidia (Pegler et al. 1998; Ramírez et al. 2017). The material of *M. titans* examined from Colombia presents the macroscopic and microscopic features described by Pegler et al. (1998), although with sizes up to 10 cm.

Habitat and distribution. Terrestrial species, growing on soil in the shade at the base of a tree or on the edge of the road, scattered and gregarious growth habits, saprotroph, cespitose, collected during the rainy season (Cossu et al. 2022). *Macrocybe titans* has a wide distribution and is found on all American continents: North America: USA (Bigelow and Kimbrough 1980), Mexico (Singer 1990; Cifuentes and Guzmán 1981), Central America: Costa Rica (Pegler et al. 1998, Calonge et al. 2007), Panama (Piepenbring 2008), South America: Argentina (Ramírez et al. 2017), Brazil (Battistin and Picciola 2015), Ecuador, Venezuela, and also in the Caribbean: Martinique, Puerto Rico, and Trinidad and Tobago (Pegler et al. 1998).

In Colombia, *M. titans* has been recorded at elevations of 500–907 m a.s.l, and it is used as human food by some indigenous ethnic groups (Cossu et al. 2022). The species was previously recorded from Antioquia, Boyacá, and Santander (Corrales and López 2005; Cossu et al. 2022), and this is the first record from Magdalena and the Colombian Caribbean region.

Agaricaceae

***Podaxis pistillaris* (L.) Fr.**

Figure 4

Material examined. COLOMBIA – **Magdalena** • Santa Marta, Universidad del Magdalena; 11°13′18″N, 074°11′08″W; 11.X.2019, J.Luna-Fontalvo et al. leg.; JLF | CAS | ABY 043; UMAG:CBUMAG:FUN:26.

Identification. Pileus ellipsoid to obtusely conical, 90–100 × 30–48 mm, orange-white (5A2) with

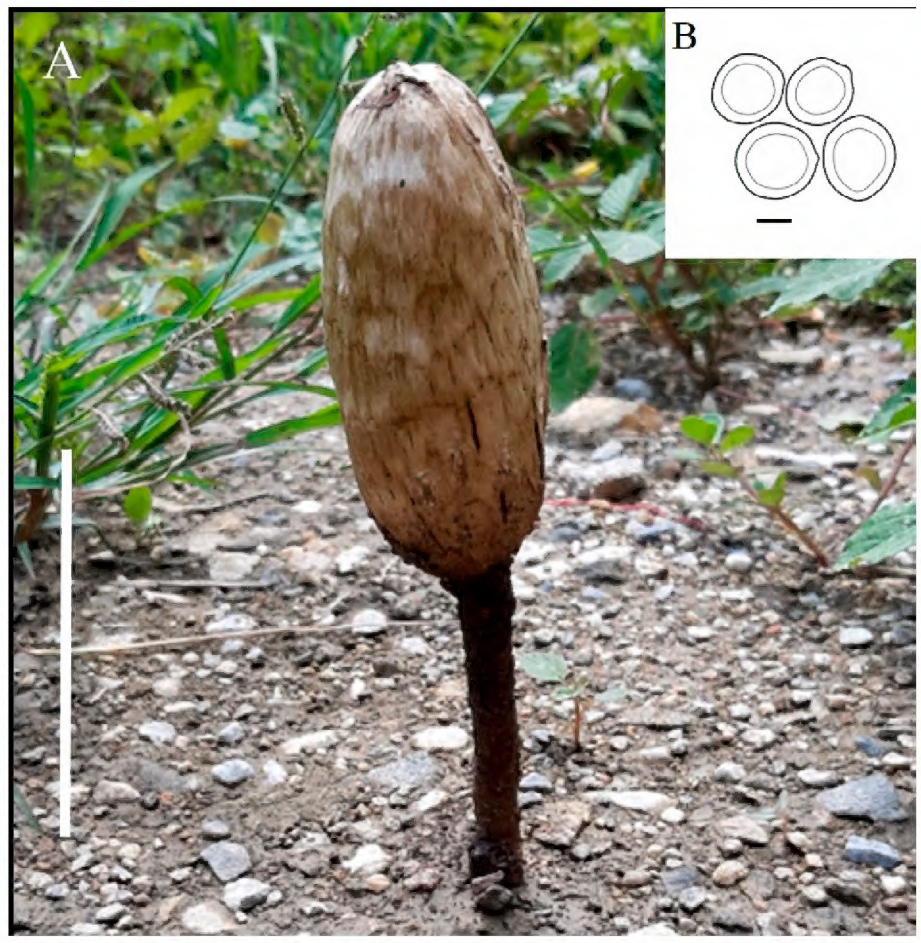

Figure 4. Basidioma and microscopic structures of *Podaxis pistillaris* **A.** Sporocarp. **B.** Spores. Scale bars: A = 4 cm; B = 10 µm.

greyish-brown spots (5D3); dry, scaly, brittle, shiny surface; edge of crown attached to stipe. Blades absent; dark brown (7F8) to black powdery tissue due to spores. Dark brown stem (7F8), 70–100 mm × 10–13 mm, cylindrical, fibrous, scaly, hard, and thickened in the basal part (Fig. 4A).

Dark brown basidiospores (7F8), measuring 8.93–10.85 × 8.12–10.17 µm, subglobose, smooth, and thick-walled, presenting a germinal pore (Fig. 4B). Basidia, Cheilocystidia and Pleurocystidia not observed.

Habitat and distribution. Terrestrial species, solitary saprotroph, present in arid, desert settings, and including wasteland, fields, and urban locations (Cossu et al. 2022). This species presents a pantropical distribution, and it is found in tropical Asia (India, China), Africa (Kenya, Madagascar, Nigeria, South Africa), the Americas (USA, Mexico, Guatemala, Brazil, Argentina), the Caribbean (Dominican Republic, Jamaica), and Australia (Watling and Gregory 1977; Wright and Albertó 2002; ColFungi 2023).

In Colombia *P. pistillaris* is distributed in La Guajira and Cesar. The use of its spores as a cosmetic and as a skin protectant in religious rituals and dances of some indigenous communities in the country has been recorded (Villalobos et al. 2017; Cossu et al. 2022).

Discussion

Three species of Agaricales are recorded from the department of Magdalena; two of them are newly reported from the Colombian Caribbean region. Thus, the number of fungi species in Magdalena is increased to 265 (ColFungi 2023), and the number of Agaricales species in this department increases to 55 (Gómez-Montoya et al. 2021; Luna-et al. 2021). *Agrocybe pediades* (Strophariaceae), *Macrocybe titans* (Callistoporiaceae) are newly recorded from the Colombian Caribbean Region. *Podaxis pistillaris* (Agaricaceae) is newly reported from the Magdalena department.

There are still unexplored areas on the Caribbean Plains; only the 6% of this region has been explored compared to 83% of the Andes region in the last 40 years (Pulido 1983; Pineda et al. 1988; Franco-Molano and Uribe-Calle 2000; Franco-Molano et al. 2010; Vasco-Palacios et al. 2013; Palacio et al. 2015; Lombana et al. 2016; Putzke et al. 2020). Therefore, our new data adds to the knowledge of macrofungi in the region. This study is our second contribution to the inventory of Agaricales in anthropized ecosystems areas of the tropical dry forest from the Caribbean Plain biogeographic region.

According to Rangel-C. (2012), the Caribbean region is the most diverse of the extra-Andean regions in Colombia. However, these estimations have considered taxonomic groups such as flowering plants, ferns, bryophytes, amphibians, reptiles, mammals, and even lichens, but not macrofungi, probably due to lack of exploration or expert taxonomists in the field.It is very likely that the number of species is much higher since the Caribbean region and Magdalena department offer a variety of ecosystems and environments that can be colonized by fungi and most of its territory has not been explored.It is necessary to carry out inventories and intensify the sampling of fungi in unexplored and scarcely explored areas. In addition, it is necessary to carry out studies in threatened ecosystems, such as tropical dry forests (Etter et al. 2017), which could harbor fungal biodiversity that may disappear without being discovered (Gómez-Montoya et al. 2021; Franco-Molano et al. 2022; Gaya et al. 2022).

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This is the scientific contribution no. 22 from the Centro de Colecciones Biológicas de la Universidad del Magdalena.

Authors' Contributions

Data curation: JALF, CA, AB, KRR. Formal analysis: JALF, CA, AB. Funding acquisition: RJG, MAN. Methodology: JALF, CA, AB. Supervision: JALF, RJG, MAN. Visualization: KRR. Project administration: JALF, RJG, MAN. Validation: KRR. Writing – original draft: JALF, CA, AB. Writing – review and editing: KRR, MAN.

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